ISSN 1330-3651 (Print), ISSN 1848-6339 (Online)
https://doi.org/10.17559/TV-20221020010813
Original scientific paper

A TOPSIS and DEA Based Approach to Evaluate the Operational Efficiency of Sponge City

Ran LI

Abstract: As an innovative means to promote low-carbon and ecological development of cities, sponge cities have attracted extensive attention from industry and scholars. Measuring the operation efficiency of a sponge city can effectively measure whether the current input and output are reasonable, whether the management and operation are scientific, etc., which can find out the weaknesses in the current process and management. This paper proposes an evaluation method of interval cross-efficiency combined with TOPSIS and DEA to measure the operating efficiency of a sponge city. Specifically, an evaluation system, that includes three inputs and six outputs, is established at first from the perspective of input and output. Secondly, due to the uncertainty of the natural environment, two DEA models of benevolent and aggressive models are adopted to obtain the cross-efficiency interval value of a sponge city. Next, the cross-efficiency interval values are aggregated based on TOPSIS, and then, the descending principle is introduced to rank sponge cities to obtain the optimal operation efficiency cities. Finally, a case is used to verify the effectiveness of the proposed method. The research idea of this paper is clear, the research method is simple, and the research results can provide a basis for building an efficient and high-level sponge city.

Keywords: cross-efficiency; DEA; evaluation; operational efficiency; sponge city; TOPSIS

1 INTRODUCTION

The process of urbanization has not only promoted social and economic development, but has also brought water problems such as waterlogging, water pollution, and water ecological imbalance [1-2]. The concept of sponge city provides new ideas for solving water problems. Sponge city is a new concept of urban rainwater and flood management, which means that a city, like a sponge, has good flexibility in environmental changes and natural disasters by rainwater [3]. It can also be called a "water elastic city". In the new situation, sponge city is an innovative expression of promoting green building construction, low-carbon city development, and the formation of a smart city [4]. It is an organic combination of green technology, social, environmental, cultural, and other factors under the background of new era characteristics.

The essence of city operation efficiency evaluation is sorting, which contains the Pareto idea, that is, the most effective management method is used to make the resource elements meet the construction demand process under the limited resource allocation [5-6]. Measuring the sponge city operation efficiency is conducive to exploring the defects in construction and management, and provides a basis for improving the level of construction and management. At present, the DEA model is widely to measure the operating efficiency of sponge cities from the perspective of input and output [7-8]. Input refers to all resources invested in the construction process, and output can be determined according to the production efficiency of different research objects.

This paper proposes an efficient method combining DEA and TOPSIS, whose main steps are as follows. In line with the concept of sponge city operation efficiency and the previous research work, this paper constructs an evaluation index system of sponge cities from input and output at first. Inputs involve financial, human and material resources, so funds, number of employees and infrastructure construction level are selected as inputs. Outputs should reflect the coordinated development of economy, environment, and society, so sustainable income, water conservancy investment, pollution control, flood control and drainage, water resource utilization and drinking water safety are selected as the outputs. Secondly, benevolent and aggressive models are employed to obtain the cross-efficiency of sponge cities. Next, TOPSIS is used to aggregate the cross-efficiency interval values to obtain the operating efficiency evaluation of sponge cities. Finally, a case is used to verify the effectiveness of the proposed method. The purposed method is to explore the optimal investment portfolio through the analysis of the operating efficiency results of the sponge city, to maximize the allocation of investment and improve the operating efficiency of the sponge city.

2 LITERATURE

At present, all the world is facing the problem of "urban disease" caused by urban flooding, water shortage and water pollution [9]. These problems have caused serious external problems and restricted the healthy development of urban economy and society [10]. As an important model for the coordinated development of social economy and ecological environment, sponge city has gradually become a research hots-pot [11].

Jin et al. (2022) pointed out that the current evaluation method of sponge city has not been perfected, it lacks systematic analysis, so effective methods should be found in the next research to achieve the goal of sponge city [12]. Chen et al. (2022) used the super-efficiency SBM model to measure the construction efficiency of 28 sponge cities in China; the results show that the construction efficiency of these 28 cities is still in a low efficiency state and the efficiency of only 9 cities is effective [13]. Li et al. (2022) has conducted research on the construction of permeable cities in sponge cities, and analyzed the economic benefits of permeable cities on sponge cities from 19 basic evaluation indicators such as environmental benefits, economic benefits, and social benefits [14]. Zhu et al. (2022) established a comprehensive benefit evaluation system, which aims to provide practical applications for solving the design problems of China's sponge cities, so as to maximize the effect [15]. Li et al. (2019) combined qualitative and quantitative analysis techniques and a broad hierarchical structure to give an evaluation system for sponge cities [16]. Wang et al. (2016) studied the connotation and construction methods of sponge city and believed that we should be paid to the individual heterogeneity of the city in construction [17]. Zhou et al. (2022) analyzed the distribution of extreme precipitation in China, and found that extreme precipitation in China showed obvious differences due to different geographical locations [18]. Zhang et al. (2018) studied the impact of surface runoff on urban water storage capacity [19]. The frequency of urban water disasters caused by rainstorm or continuous rainfall can be reduced by improving the capacity of urban drainage facilities [20-21]. Meili et al. (2020) describes plant physiological and biophysical characteristics to simulate water budget in urban environment. The results show that fencing, green coverage and biological retention system can effectively reduce the peak flow of urban runoff [22]. Luo et al. (2022) used the storm water management model (SWMM) to simulate the storage and drainage effects under different rainfall characteristics and different land cover under different rainstorm and runoff processes [23].

Sponge city is a complex system project, and its control objective is not single. Therefore, the construction of sponge city needs to establish a management response mechanism for the above control objectives, and carry out multi-target correlation analysis [24]. In recent decades, great changes have taken place in urban management. Modern information technologies such as big data [25-26], Computer Simulation [27-28] are used, which can effectively improve the level of urban intelligent management. Zhang et al. (2016) analyzed urban rainwater management modelling based on data science [29]. It should improve the management efficiency of the urban system, so as to give full play to the role of the city in carrying water resources, which has significance for the management of sponge cities [30]. In addition, the construction of sponge cities will create investment opportunities, infrastructure upgrading, engineering products and new green technologies [31].

3 PROBLEM STATEMENT

At present, urban water logging and unreasonable utilization of water resources have become increasingly prominent problems [32]. In order to effectively prevent and control urban flood runoff pollution, improve urban ecosystem functions, and achieve sustainable water cycle, the concept of sponge city was proposed. Sponge cities follow the principle of ecological priority, and can effectively absorb and release water resources. It has strong resilience in adapting to environmental changes and responding to natural disasters. We can effectively understand the efficiency of capital investment and city management by measuring the operating efficiency of the sponge city, to achieve a comprehensive evaluation of the sponge city. Therefore, it is worth paying attention to the research problem about the measurement of the sponge city's operation efficiency. The focus of the research on the operating efficiency of sponge cities is how to maximize the efficiency of limited resources through reasonable allocation. However, the current measurement of sponge city's operation efficiency has problems such as high uncertainty of the evaluation environment, imperfect evaluation index system, and imperfect evaluation methods. Therefore, it is crucial to establish a scientific and reasonable evaluation index system and improve the evaluation methods of operating efficiency to ensure the optimal construction of sponge cities. In view of the above problems, this paper proposes a cross-efficiency evaluation method, aiming to fill the gap of the sponge city's operation efficiency. The logic structure of the proposed method is shown below (Fig. 1).

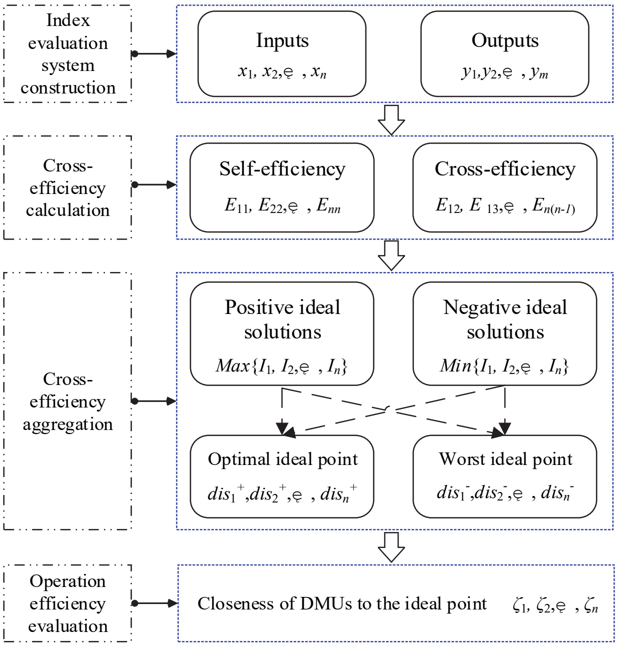

Figure 1 The logic structure of the proposed method

4 MODEL

4.1 Prepare

To facilitate the understanding of the subsequent research, the basic properties of interval numbers are introduced here [33].

Definition 1 There is an interval number, $a=[a^L, a^B]$. If $0 \le a^L < a^B$, a is a nonnegative interval number. If $0 \le a^L = a^B$, a is a nonnegative real number.

Definitions 2 $a=[a^L, a^B]$ and $b=[b^L, b^B]$ are any two interval numbers,

- $a+b=[a^L, a^B]+[b^L, b^B]=[a^L+b^L, a^B+b^B]$
- $\lambda a=\lambda[a^L, a^B]=[\lambda a^L, \lambda a^B]$, $\lambda \neq 0$. If $\lambda = 0$, $\lambda a = 0$.

Definitions 3 $a=[a^L, a^B]$ and $b=[b^L, b^B]$ are any two interval numbers. The probability of b greater than a can be calculated by the following.

$$P(b \ge a)=\frac{\max\{0, b^B-a^L\}-\max\{0, b^L-a^U\}}{a^B-a^L+b^B-b^L} \tag{1}$$

Especially, if $a^L > b^L$ and $a^B > b^B$, we can consider $a > b$.

Definitions 4 $a = [a^L, a^B]$ and $b = [b^L, b^B]$ are any two interval numbers. The distance between b and a is

(Hamming) distance

$$d = \frac{1}{2}\left(\left|a^L - b^L\right| + \left|a^B - b^B\right|\right) \tag{2}$$

(Euclidean) distance

$$d = \sqrt{\frac{1}{2}\left(\left(a^L - b^L\right)^2 + \left(a^B - b^B\right)^2\right)} \tag{3}$$

(Hausdorff) distance

$$d = \left|\frac{1}{2}\left(\left(a^L + a^B\right) - \left(b^L + b^B\right)\right)\right| + \left|\frac{1}{2}\left(\left(a^B - a^L\right) - \left(b^B - b^L\right)\right)\right| \tag{4}$$

Definition 5 There are any two interval numbers $a = [a^L, a^B]$, $b = [b^L, b^B]$, whose center distance is

$$\Delta(d) = \frac{1}{2}\left(\left(a^L + a^B\right) - \left(b^L + b^B\right)\right) \tag{5}$$

4.2 Cross-Efficiency DEA Model

4.2.1 Self-Efficiency

Data envelopment analysis (DEA), proposed by Charnes (1978) [34], is a linear programming methodology for measuring relative efficiency of DMUs. This method avoids the impact of index weights' subjectivity on the evaluation results, so it is widely used in efficiency evaluation of various industries.

Let us suppose there are n decision making units (DMU_i, $i = 1,\dots,n$). DMU_i inputs j resources to obtain m outputs, that is j input indicators and m output indicators, as x_{ij} ($j = 1,\dots,s$) and y_{ik} ($k = 1,\dots,m$). If we want to obtain the maximum efficiencies of DMUs, the following CCR model can be used to compute the efficiencies of DMUs.

$$\begin{aligned}
&\max E_{ii} = \frac{\sum_{k=1}^{m} u_{ik} y_{ik}}{\sum_{j=1}^{s} v_{ij} x_{ij}} \\
&\text{s.t.} E_{rr} = \frac{\sum_{k=1}^{m} u_{rk} y_{rk}}{\sum_{j=1}^{s} v_{rj} x_{rj}}; \\
&u_{ik} \ge 0; v_{ij} \ge 0; \\
&i = 1,\dots,n; r = 1,\dots,n; \\
&k = 1,\dots,m; j = 1,\dots,s.
\end{aligned} \tag{6}$$

Here, E_{ii} denotes the efficiency value of the DMU_i, that is self-efficiency; v_{ij} and u_{ik} denote the weights of the j input and the m output.

Using the Charnes-Cooper, Eq. (6) can be transformed into the following equivalent linear programming problem.

$$\begin{aligned}
&\max E_{ii} = \sum_{k=1}^{m} u_{ik} y_{ik} \\
&\text{s.t.} \sum_{k=1}^{m} u_{rk} y_{ik} - \sum_{j=1}^{s} v_{rj} x_{ij} \le 0; \\
&\sum_{j=1}^{s} v_{ij} x_{ij} = 1; \\
&i = 1,\dots,n; r = 1,\dots,n; \\
&k = 1,\dots,m; j = 1,\dots,s.
\end{aligned} \tag{7}$$

Eq. (7) allows DMU_i to select the most favorable weight to achieve the maximum self-efficiency, which is recorded as u_{ik}^* and v_{ij}^*. Here $v^* = \left(v_{i1}^*, v_{i2}^*, \cdots, v_{is}^*\right)$ and $u^* = \left(u_{i1}^*, u_{i2}^*, \cdots, u_{im}^*\right)$ is also the best solution of Eq. (7).

4.2.2 Cross-Efficiency

Since the self-efficiency of Eq. (7) is prone to the situation that multiple DMUs have the same efficiency, the decision-maker cannot distinguish between the advantages and disadvantages of DMUs [35]. Therefore, on the basis of traditional self-efficiency model, scholars introduced the idea of other evaluation and adopted quadratic programming strategy to obtain the efficiency of other evaluation of decision-making units. The most classic evaluation models are benevolent and aggressive models.

The benevolent model emphasizes that the score of other evaluation efficiency is also maximized under the condition of self-efficiency it is the largest, which is shown as follows.

$$\begin{aligned}
&\max E_{ir} = \sum_{k=1}^{m} u_{ik} \left(\sum_{r=1, r\ne i}^{n} y_{rk}\right) \\
&\text{s.t.} \sum_{j=1}^{s} v_{rj} \left(\sum_{r=1, r\ne i}^{s} x_{ij}\right) = 1; \\
&\sum_{k=1}^{m} u_{ik} y_{ik} - E_{ii} \sum_{j=1}^{s} v_r x_{rj} = 0; \\
&\sum_{k=1}^{m} u_{rk} y_{ik} - \sum_{j=1}^{s} v_{ij} x_{ij} \le 0; \\
&u \ge 0; v \ge 0; \\
&i = 1,\dots,n; r = 1,\dots,n; \\
&k = 1,\dots,m; j = 1,\dots,s.
\end{aligned} \tag{8}$$

The aggressive model emphasizes that the score of other evaluation efficiency is also minimized under the condition of self-efficiency it is the largest, which is shown as follows.

$$
\begin{aligned}
&\min E_{ir} = \sum_{k=1}^{m} u_{ik} \left(\sum_{r=1,r\neq i}^{n} y_{rk} \right) \\
&\text{s.t.} \sum_{j=1}^{s} v_{rj} \left(\sum_{r=1,r\neq i}^{s} x_{ij} \right) = 1; \\
&\sum_{k=1}^{m} u_{ik} y_{ik} - E_{ii} \sum_{j=1}^{s} v_r x_{rj} = 0; \\
&\sum_{k=1}^{m} u_{rk} y_{ik} - \sum_{j=1}^{s} v_{ij} x_{ij} \leq 0; \\
&u \geq 0; v \geq 0; \\
&i = 1,\dots,n; r = 1,\dots,n; \\
&k = 1,\dots,m; j = 1,\dots,s.
\end{aligned}
\tag{9}
$$

E_{ir} is cross-efficiency in Eqs. (8) to (9). Eq. (8) and Eq. (9) have the same constraint conditions, but the difference is the objective. Specifically, the objective of Eq. (8) is maximization, which means to maximize the efficiency of other decision-making units under the self-efficiency of DMU_i remain unchanged. On the contrary, the objective of Eq. (9) is minimization, which means to minimize the efficiency of other decision-making units under the self-efficiency of DMU_i remain unchanged. In line with Eq. (7) and Eq. (8) or Eq. (9), we can get self-efficiency and peer-efficiency values for each DMU.

4.2.3 Interval Cross-Efficiency

The interval cross-efficiency evaluation strategy considers all possible weight schemes in the weight space, and defines the cross-efficiency of DMUs to a certain efficiency interval [36].

Assuming that DMU_i is an evaluation unit and DMU_r is an evaluated unit. In the cross-efficiency stage, DMU_r can obtain the largest cross-efficiency on the premise that E_{ii} keeps unchanged. It can be calculated as follows.

$$
\begin{aligned}
&\max \overline{E}_{ir} = \sum_{k=1}^{m} u_{ik} \left(\sum_{r=1,r\neq i}^{n} y_{rk} \right) \\
&\text{s.t.} \sum_{j=1}^{s} v_{rj} \left(\sum_{r=1,r\neq i}^{s} x_{ij} \right) = 1; \\
&\sum_{k=1}^{m} u_{ik} y_{ik} - E_{ii} \sum_{j=1}^{s} v_r x_{rj} = 0; \\
&\sum_{k=1}^{m} u_{rk} y_{ik} - \sum_{j=1}^{s} v_{ij} x_{ij} \leq 0; \\
&u \geq 0; v \geq 0; \\
&i = 1,\dots,n; r = 1,\dots,n; \\
&k = 1,\dots,m; j = 1,\dots,s.
\end{aligned}
\tag{10}
$$

Similarly, the minimized cross-efficiency of DMU_r can be solved by Eq. (11).

$$
\begin{aligned}
&\min \underline{E}_{ir} = \sum_{k=1}^{m} u_{ik} \left(\sum_{r=1,r\neq i}^{n} y_{rk} \right) \\
&\text{s.t.} \sum_{j=1}^{s} v_{rj} \left(\sum_{r=1,r\neq i}^{s} x_{ij} \right) = 1; \\
&\sum_{k=1}^{m} u_{ik} y_{ik} - E_{ii} \sum_{j=1}^{s} v_r x_{rj} = 0; \\
&\sum_{k=1}^{m} u_{rk} y_{ik} - \sum_{j=1}^{s} v_{ij} x_{ij} \leq 0; \\
&u \geq 0; v \geq 0; \\
&i = 1,\dots,n; r = 1,\dots,n; \\
&k = 1,\dots,m; j = 1,\dots,s.
\end{aligned}
\tag{11}
$$

It is not difficult to find that Eq. (10) and Eq. (8) belong to one kind of benevolent model, and Eq. (11) and Eq. (9) are aggressive models. The constraint space of Eq. (10) or Eq. (11) is linear, and the objective is convex. Therefore, the cross-efficiency value of DMU_i to DMU_r can be defined on an interval. The lower and upper bound of the cross efficiency interval are obtained by solving Eq. (10) and Eq. (11), that is, the cross efficiency of DMU_i to DMU_r should be located on the interval, $[\underline{E}_{ir}, \overline{E}_{ir}]$.

Based on this, we can get the cross-efficiency interval values of each decision-making unit, as shown in Tab. 1.

Table 1 The cross-efficiency matrix of DMUs

	$DMU1$	$DMU2$	$\cdots$	$DMUn$
$DMU1$	$[\underline{E}_{11}, \overline{E}_{11}]$	$[\underline{E}_{12}, \overline{E}_{12}]$	$\cdots$	$[\underline{E}_{1n}, \overline{E}_{1n}]$
$DMU2$	$[\underline{E}_{21}, \overline{E}_{21}]$	$[\underline{E}_{22}, \overline{E}_{22}]$	$\cdots$	$[\underline{E}_{2n}, \overline{E}_{2n}]$
$\vdots$	$\vdots$	$\vdots$	$\cdots$	$\vdots$
$DMUn$	$[\underline{E}_{n1}, \overline{E}_{n1}]$	$[\underline{E}_{n2}, \overline{E}_{n2}]$	$\cdots$	$[\underline{E}_{nn}, \overline{E}_{nn}]$

4.3 Operation Efficiency Based on TOPSIS

TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) is a common decision-making method for multi-attribute and multi-objective decision analysis in systems engineering [37]. TOPSIS is a ranking method according to the closeness of a limited number of evaluation objects to the ideal target, which can evaluate the relative merits of the evaluation objects. The steps of interval TOPSIS are similar to those of classical TOPSIS, mainly including the following basic steps.

Tab. 1 gives a cross-efficiency interval matrix, it is standardized at first by Eqs. (12) to (13), [38].

$$
\underline{E}_{ir}^{*} = \frac{\underline{E}_{ir}}{\sqrt{\sum_{i=1}^{n} \left(\underline{E}_{ir}\right)^2 + \sum_{i=1}^{n} \left(\overline{E}_{ir}\right)^2}}
\tag{12}
$$

$$
\overline{E}_{ir}^{*} = \frac{\overline{E}_{ir}}{\sqrt{\sum_{i=1}^{n} \left(\underline{E}_{ir}\right)^2 + \sum_{i=1}^{n} \left(\overline{E}_{ir}\right)^2}}
\tag{13}
$$

Next, the weighted standardized matrix is constructed. Let $M = \left(m_{ir}\right)_{n\times n}$ denote the weighted standardized matrix. According to the definition of interval number, m_{ir} can be calculated by Eq. (14).

$$m_{ir} = \lambda_r \left[\underline{E}_{ir}^*, \overline{E}_{ir}^*\right] = \left[\lambda_r \underline{E}_{ir}^*, \lambda_r \overline{E}_{ir}^*\right] \tag{14}$$

Here, λ_r denotes a weight, $0 \le \lambda_r$, $\sum_{r=1}^{n} \lambda_r = 1$.

The positive ideal solutions (PIS) and negative ideal solutions (NIS) of the matrix are based on the weighted standardized matrix, as shown in Eqs. (15) to (16).

$$I^{\max} = \left(m_{1r}^{\max}, m_{2r}^{\max}, \cdots, m_{nr}^{\max}\right) \tag{15}$$

$$I^{\min} = \left(m_{1r}^{\min}, m_{2r}^{\min}, \cdots, m_{nr}^{\min}\right) \tag{16}$$

Owing to m_{ir} being an interval number, PIS and NIS are also interval numbers, as shown below.

$$\text{PIS: } I_r^{\max} = \left[\max_{i=1,\cdots,n}\left(\lambda_r \underline{E}_{ir}^*\right), \max_{i=1,\cdots,n}\left(\lambda_r \overline{E}_{ir}^*\right)\right] \tag{17}$$

$$\text{NIS: } I_r^{\min} = \left[\min_{i=1,\cdots,n}\left(\lambda_r \underline{E}_{ir}^*\right), \min_{i=1,\cdots,n}\left(\lambda_r \overline{E}_{ir}^*\right)\right]_{1\times n} \tag{18}$$

Furthermore, the distance between each DMU and PIS and NIS can be calculated by Eqs. (19) to (20).

$$\begin{aligned} dis_i^+ &= \sum_{r=1}^{n} \left\| m_{ir} - I_r^{\max} \right\| \\ &= \sum_{r=1}^{n} \frac{1}{2} \left| \lambda_r \underline{E}_{ir}^* - \max_{i=1,\cdots,n}\left(\lambda_r \underline{E}_{ir}^*\right) \right| + \sum_{r=1}^{n} \frac{1}{2} \left| \lambda_r \overline{E}_{ir}^* - \max_{i=1,\cdots,n}\left(\lambda_r \overline{E}_{ir}^*\right) \right| \end{aligned} \tag{19}$$

$$\begin{aligned} dis_i^- &= \sum_{r=1}^{n} \left\| m_{ir} - I_r^{\min} \right\| \\ &= \sum_{r=1}^{n} \frac{1}{2} \left| \lambda_r \underline{E}_{ir}^* - \min_{i=1,\cdots,n}\left(\lambda_r \underline{E}_{ir}^*\right) \right| + \sum_{r=1}^{n} \frac{1}{2} \left| \lambda_r \overline{E}_{ir}^* - \min_{i=1,\cdots,n}\left(\lambda_r \overline{E}_{ir}^*\right) \right| \end{aligned} \tag{20}$$

According to the distance of PIS and NIS calculated by Eqs. (19) to (20), further calculate the closeness of each decision-making unit to the ideal point by Eq. (21).

$$\xi_i = \frac{dis_i^-}{dis_i^+ + dis_i^-} \tag{21}$$

Here, ξ_i denotes the closeness between DMU_i and ideal point.

The larger the ξ_i, the closer the optimal ideal point and the farther the worst ideal point. According to the closeness of each DMU to the ideal point, combined with the principle of descending order, all decision-making units are sorted to find the decision-making unit with the best efficiency.

5 SIMULATION ANALYSIS

Sponge city means that a city can be like a sponge with good "elasticity" in adapting to environmental changes and responding to natural disasters. The construction of sponge cities should follow the principle of ecological priority, combine natural approaches with artificial measures, maximize the storage, infiltration and purification of rainwater in urban areas, and promote the utilization of rainwater resources and ecological environment protection on the premise of ensuring the safety of urban drainage and waterlogging prevention.

Combined with the literature [39-40], an index system of sponge city operation efficiency is constructed from the perspective of input and output. The operation of a sponge city involves three elements: financial resources, human resources and material resources. Therefore, funds, number of employees, and infrastructure construction level are selected as inputs. The core of the sponge city achieves the coordinated development of "economy-environment-society" in terms of water issues. Therefore, sustainable income, water conservancy investment, pollution control, flood control and drainage, water resource utilization, and drinking water safety are selected as outputs.

Table 2 Sponge city operational efficiency measurement index system

Type	Indexes	Symbol	Illustrate
Inputs	Funds	$x1$	Investable capital resources
	Number of employees	$x2$	Number of relevant employees
	Infrastructure construction level	$x3$	Urban drainage pipeline, Length of flood dike, etc.
Outputs	Sustainable income	$y1$	Urban sustainable development capacity
	Water conservancy investment	$y2$	Fixed assets investment in water industries
	Pollution control	$y3$	Water function area compliance rate, sewage treatment rate, etc.
	Flood control and drainage	$y4$	Runoff reduction rate, rainwater sewage confluence ratio, etc.
	Water resource utilization	$y5$	Surface water resources, groundwater resources, sewage recycling, etc.
	Drinking water safety	$y6$	Tap water penetration rate, drinking water source quality standard rate, etc.

Assume that it is necessary to evaluate the operational efficiency of 15 sponge cities, and randomly assign the index system of inputs-outputs between intervals [0,25]. The initial data evaluation matrix is shown in Tab. 3.

Substitute the data in Tab. 3 into Eqs. (10) to (11) and solve it. The cross-efficiency obtained by solving the aggressive model is regarded as the minimum value of operating-efficiency; the cross-efficiency obtained by solving the benevolent model is regarded as the maximum value of operating efficiency. Based on this, the cross efficiency interval values of sponge cities are obtained as shown in Tab. 4.

Further, the cross-efficiency interval values in Tab. 4 are standardized according to Eqs. (12) to (13). The standardized values are shown in Tab. 5.

Table 3 Initial data

City	*x*1	*x*2	*x*3	*y*1	*y*2	*y*3	*y*4	*y*5	*y*6
1	24	5	4	1	14	15	1	12	6
2	7	10	23	13	8	16	14	3	22
3	15	24	13	18	13	16	21	5	10
4	17	19	11	20	2	4	1	11	16
5	14	21	5	7	19	14	24	11	15
6	7	20	10	24	11	19	18	12	8
7	21	23	16	11	12	13	19	5	22
8	5	11	19	10	15	9	10	22	15
9	6	5	6	7	8	9	25	2	6
10	9	12	15	3	15	3	6	20	2
11	12	20	1	22	1	7	14	22	19
12	15	19	12	21	9	8	24	25	14
13	15	13	6	12	20	7	4	22	3
14	20	22	7	18	18	6	5	4	9
15	14	14	17	5	18	22	7	22	25

Table 4 Interval cross-efficiency

City	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	[1.000, 1.000]	[0.060, 1.000]	[0.087, 0.681]	[0.038, 0.777]	[0.218, 1.000]	[0.196, 1.000]	[0.091, 0.710]	[0.130, 1.000]	[0.129, 1.000]	[0.054, 0.882]	[0.018, 1.000]	[0.140, 1.000]	[0.179, 1.000]	[0.076, 0.827]	[0.306, 1.000]
2	[0.047, 1.000]	[1.000, 1.000]	[0.189, 0.648]	[0.094, 0.840]	[0.258, 1.000]	[0.182, 1.000]	[0.283, 0.704]	[0.543, 1.000]	[0.318, 1.000]	[0.071, 0.559]	[0.191, 1.000]	[0.238, 0.987]	[0.064, 0.868]	[0.133, 0.688]	[0.258, 1.000]
3	[1.000, 1.000]	[0.559, 0.559]	[0.681, 0.681]	[0.463, 0.463]	[1.000, 1.000]	[1.000, 1.000]	[0.523, 0.523]	[0.599, 0.599]	[1.000, 1.000]	[0.394, 0.394]	[1.000, 1.000]	[0.642, 0.642]	[1.000, 1.000]	[0.788, 0.788]	[0.773, 0.773]
4	[0.154, 0.154]	[0.771, 0.771]	[0.611, 0.611]	[0.850, 0.850]	[0.290, 0.290]	[0.986, 0.986]	[0.377, 0.377]	[0.591, 0.591]	[1.000, 1.000]	[0.177, 0.177]	[1.000, 1.000]	[0.883, 0.883]	[0.765, 0.765]	[0.699, 0.699]	[0.254, 0.254]
5	[0.176, 1.000]	[0.089, 1.000]	[0.256, 0.681]	[0.031, 0.594]	[1.000, 1.000]	[0.287, 1.000]	[0.193, 0.701]	[0.181, 1.000]	[0.336, 1.000]	[0.110, 0.854]	[0.067, 1.000]	[0.197, 0.872]	[0.319, 1.000]	[0.239, 0.843]	[0.181, 1.000]
6	[0.012, 1.000]	[0.312, 1.000]	[0.316, 0.681]	[0.060, 0.850]	[0.146, 1.000]	[1.000, 1.000]	[0.150, 0.644]	[0.278, 1.000]	[0.302, 1.000]	[0.090, 0.840]	[0.142, 1.000]	[0.196, 1.000]	[0.143, 1.000]	[0.105, 0.843]	[0.104, 1.000]
7	[0.785, 0.785]	[0.913, 0.913]	[0.383, 0.383]	[0.603, 0.603]	[0.735, 0.735]	[0.381, 0.381]	[0.713, 0.713]	[0.671, 0.671]	[1.000, 1.000]	[0.123, 0.123]	[1.000, 1.000]	[0.622, 0.622]	[0.204, 0.204]	[0.357, 0.357]	[1.000, 1.000]
8	[0.047, 1.000]	[0.097, 1.000]	[0.076, 0.670]	[0.036, 0.834]	[0.179, 1.000]	[0.298, 1.000]	[0.054, 0.676]	[1.000, 1.000]	[0.076, 1.000]	[0.096, 0.882]	[0.028, 1.000]	[0.200, 1.000]	[0.080, 1.000]	[0.045, 0.800]	[0.275, 1.000]
9	[0.010, 1.000]	[0.154, 1.000]	[0.175, 0.681]	[0.011, 0.850]	[0.229, 1.000]	[0.180, 1.000]	[0.165, 0.713]	[0.130, 1.000]	[1.000, 1.000]	[0.096, 0.868]	[0.037, 1.000]	[0.242, 1.000]	[0.062, 1.000]	[0.045, 0.840]	[0.099, 1.000]
10	[1.000, 1.000]	[0.134, 0.134]	[0.128, 0.128]	[0.343, 0.343]	[0.340, 0.340]	[0.381, 0.381]	[0.126, 0.126]	[1.000, 1.000]	[0.206, 0.206]	[0.882, 0.882]	[0.751, 0.751]	[0.779, 0.779]	[1.000, 1.000]	[0.113, 0.113]	[0.819, 0.819]
11	[0.011, 1.000]	[0.006, 1.000]	[0.017, 0.681]	[0.006, 0.850]	[0.064, 1.000]	[0.042, 1.000]	[0.014, 0.713]	[0.024, 1.000]	[0.015, 1.000]	[0.007, 0.875]	[1.000, 1.000]	[0.061, 1.000]	[0.026, 1.000]	[0.026, 0.843]	[0.013, 1.000]
12	[0.354, 1.000]	[0.294, 0.965]	[0.318, 0.582]	[0.332, 0.836]	[0.329, 0.641]	[0.595, 1.000]	[0.280, 0.405]	[0.913, 1.000]	[0.843, 1.000]	[0.441, 0.862]	[0.951, 1.000]	[1.000, 1.000]	[0.888, 1.000]	[0.163, 0.632]	[0.489, 0.811]
13	[0.397, 1.000]	[0.073, 0.865]	[0.118, 0.681]	[0.058, 0.818]	[0.333, 1.000]	[0.334, 1.000]	[0.109, 0.653]	[0.257, 1.000]	[0.149, 1.000]	[0.289, 0.882]	[0.038, 1.000]	[0.244, 1.000]	[1.000, 1.000]	[0.113, 0.843]	[0.312, 1.000]
14	[0.450, 0.450]	[0.357, 0.357]	[0.611, 0.611]	[0.384, 0.384]	[1.000, 1.000]	[1.000, 1.000]	[0.391, 0.391]	[0.564, 0.564]	[0.727, 0.727]	[0.466, 0.466]	[1.000, 1.000]	[0.586, 0.586]	[1.000, 1.000]	[0.843, 0.843]	[0.506, 0.506]
15	[0.285, 1.000]	[0.379, 1.000]	[0.189, 0.663]	[0.146, 0.753]	[0.372, 1.000]	[0.259, 1.000]	[0.249, 0.713]	[0.510, 1.000]	[0.396, 1.000]	[0.092, 0.795]	[0.243, 1.000]	[0.336, 0.931]	[0.154, 1.000]	[0.147, 0.782]	[1.000, 1.000]

Table 5 Standardized Interval cross-efficiency

City	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	[1.000, 1.000]	[0.060, 1.000]	[0.087, 0.681]	[0.038, 0.777]	[0.218, 1.000]	[0.196, 1.000]	[0.091, 0.710]	[0.130, 1.000]	[0.129, 1.000]	[0.054, 0.882]	[0.018, 1.000]	[0.140, 1.000]	[0.179, 1.000]	[0.076, 0.827]	[0.306, 1.000]
2	[0.047, 1.000]	[1.000, 1.000]	[0.189, 0.648]	[0.094, 0.840]	[0.258, 1.000]	[0.182, 1.000]	[0.283, 0.704]	[0.543, 1.000]	[0.318, 1.000]	[0.071, 0.559]	[0.191, 1.000]	[0.238, 0.987]	[0.064, 0.868]	[0.133, 0.688]	[0.258, 1.000]
3	[1.000, 1.000]	[0.559, 0.559]	[0.681, 0.681]	[0.463, 0.463]	[1.000, 1.000]	[1.000, 1.000]	[0.523, 0.523]	[0.599, 0.599]	[1.000, 1.000]	[0.394, 0.394]	[1.000, 1.000]	[0.642, 0.642]	[1.000, 1.000]	[0.788, 0.788]	[0.773, 0.773]
4	[0.154, 0.154]	[0.771, 0.771]	[0.611, 0.611]	[0.850, 0.850]	[0.290, 0.290]	[0.986, 0.986]	[0.377, 0.377]	[0.591, 0.591]	[1.000, 1.000]	[0.177, 0.177]	[1.000, 1.000]	[0.883, 0.883]	[0.765, 0.765]	[0.699, 0.699]	[0.254, 0.254]
5	[0.176, 1.000]	[0.089, 1.000]	[0.256, 0.681]	[0.031, 0.594]	[1.000, 1.000]	[0.287, 1.000]	[0.193, 0.701]	[0.181, 1.000]	[0.336, 1.000]	[0.110, 0.854]	[0.067, 1.000]	[0.197, 0.872]	[0.319, 1.000]	[0.239, 0.843]	[0.181, 1.000]
6	[0.012, 1.000]	[0.312, 1.000]	[0.316, 0.681]	[0.060, 0.850]	[0.146, 1.000]	[1.000, 1.000]	[0.150, 0.644]	[0.278, 1.000]	[0.302, 1.000]	[0.090, 0.840]	[0.142, 1.000]	[0.196, 1.000]	[0.143, 1.000]	[0.105, 0.843]	[0.104, 1.000]
7	[0.785, 0.785]	[0.913, 0.913]	[0.383, 0.383]	[0.603, 0.603]	[0.735, 0.735]	[0.381, 0.381]	[0.713, 0.713]	[0.671, 0.671]	[1.000, 1.000]	[0.123, 0.123]	[1.000, 1.000]	[0.622, 0.622]	[0.204, 0.204]	[0.357, 0.357]	[1.000, 1.000]
8	[0.047, 1.000]	[0.097, 1.000]	[0.076, 0.670]	[0.036, 0.834]	[0.179, 1.000]	[0.298, 1.000]	[0.054, 0.676]	[1.000, 1.000]	[0.076, 1.000]	[0.096, 0.882]	[0.028, 1.000]	[0.200, 1.000]	[0.080, 1.000]	[0.045, 0.800]	[0.275, 1.000]
9	[0.010, 1.000]	[0.154, 1.000]	[0.175, 0.681]	[0.011, 0.850]	[0.229, 1.000]	[0.180, 1.000]	[0.165, 0.713]	[0.130, 1.000]	[1.000, 1.000]	[0.096, 0.868]	[0.037, 1.000]	[0.242, 1.000]	[0.062, 1.000]	[0.045, 0.840]	[0.099, 1.000]
10	[1.000, 1.000]	[0.134, 0.134]	[0.128, 0.128]	[0.343, 0.343]	[0.340, 0.340]	[0.381, 0.381]	[0.126, 0.126]	[1.000, 1.000]	[0.206, 0.206]	[0.882, 0.882]	[0.751, 0.751]	[0.779, 0.779]	[1.000, 1.000]	[0.113, 0.113]	[0.819, 0.819]
11	[0.011, 1.000]	[0.006, 1.000]	[0.017, 0.681]	[0.006, 0.850]	[0.064, 1.000]	[0.042, 1.000]	[0.014, 0.713]	[0.024, 1.000]	[0.015, 1.000]	[0.007, 0.875]	[1.000, 1.000]	[0.061, 1.000]	[0.026, 1.000]	[0.026, 0.843]	[0.013, 1.000]
12	[0.354, 1.000]	[0.294, 0.965]	[0.318, 0.582]	[0.332, 0.836]	[0.329, 0.641]	[0.595, 1.000]	[0.280, 0.405]	[0.913, 1.000]	[0.843, 1.000]	[0.441, 0.862]	[0.951, 1.000]	[1.000, 1.000]	[0.888, 1.000]	[0.163, 0.632]	[0.489, 0.811]
13	[0.397, 1.000]	[0.073, 0.865]	[0.118, 0.681]	[0.058, 0.818]	[0.333, 1.000]	[0.334, 1.000]	[0.109, 0.653]	[0.257, 1.000]	[0.149, 1.000]	[0.289, 0.882]	[0.038, 1.000]	[0.244, 1.000]	[1.000, 1.000]	[0.113, 0.843]	[0.312, 1.000]
14	[0.450, 0.450]	[0.357, 0.357]	[0.611, 0.611]	[0.384, 0.384]	[1.000, 1.000]	[1.000, 1.000]	[0.391, 0.391]	[0.564, 0.564]	[0.727, 0.727]	[0.466, 0.466]	[1.000, 1.000]	[0.586, 0.586]	[1.000, 1.000]	[0.843, 0.843]	[0.506, 0.506]
15	[0.285, 1.000]	[0.379, 1.000]	[0.189, 0.663]	[0.146, 0.753]	[0.372, 1.000]	[0.259, 1.000]	[0.249, 0.713]	[0.510, 1.000]	[0.396, 1.000]	[0.092, 0.795]	[0.243, 1.000]	[0.336, 0.931]	[0.154, 1.000]	[0.147, 0.782]	[1.000, 1.000]

It can be seen from the above table that the positive ideal solutions and negative ideal solutions can be obtained as follows.

$$I_1^{\max} = [0.242, 0.242],\ I_1^{\min} = [0.000, 0.006];$$
$$I_2^{\max} = [0.260, 0.260],\ I_2^{\min} = [0.000, 0.005];$$
$$I_3^{\max} = [0.168, 0.168],\ I_3^{\min} = [0.000, 0.006];$$
$$I_4^{\max} = [0.232, 0.232],\ I_4^{\min} = [0.000, 0.038];$$
$$I_5^{\max} = [0.246, 0.246],\ I_5^{\min} = [0.001, 0.021];$$
$$I_6^{\max} = [0.234, 0.234],\ I_6^{\min} = [0.000, 0.034];$$
$$I_7^{\max} = [0.192, 0.192],\ I_7^{\min} = [0.000, 0.006];$$
$$I_8^{\max} = [0.239, 0.239],\ I_8^{\min} = [0.000, 0.076];$$
$$I_9^{\max} = [0.227, 0.227],\ I_9^{\min} = [0.000, 0.010];$$
$$I_{10}^{\max} = [0.250, 0.250],\ I_{10}^{\min} = [0.000, 0.005];$$
$$I_{11}^{\max} = [0.217, 0.217],\ I_{11}^{\min} = [0.000, 0.123];$$
$$I_{12}^{\max} = [0.249, 0.249],\ I_{12}^{\min} = [0.001, 0.086];$$
$$I_{13}^{\max} = [0.229, 0.229],\ I_{13}^{\min} = [0.000, 0.010];$$
$$I_{14}^{\max} = [0.220, 0.220],\ I_{14}^{\min} = [0.000, 0.004];$$
$$I_{15}^{\max} = [0.246, 0.246],\ I_1^{\min} = [0.000, 0.016].$$

The distance between each sponge city and the positive (dis_i^+) and negative ideal solutions (dis_i^-) is calculated by Eqs. (19) to (20). These data are shown in Tab. 6.

Table 6 The information of dis_i^+ and dis_i^-

City	dis_i^+	dis_i^-	City	dis_i^+	dis_i^-
1	1.592	1.637	9	1.580	1.649
2	1.647	1.582	10	1.923	1.306
3	1.058	2.172	11	1.618	1.612
4	1.590	1.640	12	1.305	1.924
5	1.621	1.608	13	1.571	1.658
6	1.568	1.662	14	1.568	1.661
7	1.609	1.621	15	1.536	1.694
8	1.599	1.630			

Further, the closeness between the sponge city and the ideal point can be obtained according to Eq. (21), ξ_i .

Table 7 The closeness of sponge city

City	ξ_i	Rank	City	ξ_i	Rank
1	0.507	9	9	0.511	7
2	0.490	14	10	0.405	15
3	0.672	1	11	0.499	12
4	0.508	8	12	0.596	2
5	0.498	13	13	0.513	6
6	0.515	4	14	0.514	5
7	0.502	11	15	0.524	3

To better see the operation efficiency of each sponge city, its ranking is plotted in the radar chart, as shown in Fig. 2.

It can be seen from Tab. 7 that City 3 has the closest proximity to the ideal point among the 15 sponge cities, indicating that City 3 has the largest input-output efficiency ratio. On the contrary, City 10 is the farthest from the ideal point, indicating that City 3 has the lowest input-output efficiency ratio. Therefore, when we rebuild or construct water conservancy projects in the city, we can give priority to the investment portfolio of City 3 and possibly avoid the investment portfolio of City 5.

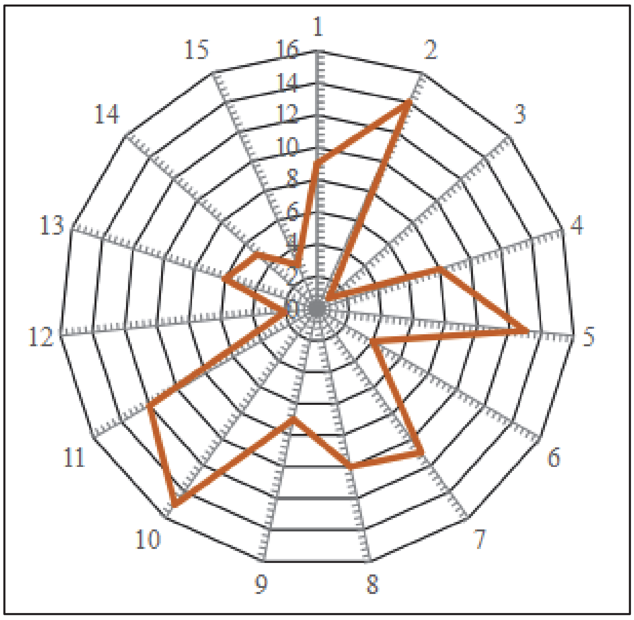

Figure 2 Operational efficiency radar chart

6 CONCLUSION

In this paper, we propose an efficiency measure that combines cross-efficiency with the ideal solution. This method first obtains the minimum and maximum values of the sponge city's operating efficiency through the benevolent model and the aggressive model and then uses TOPSIS and the interval distance formula to obtain the distance and closeness between the sponge city and the positive and negative ideal solutions. The higher the degree of closeness, the closer the operating efficiency of the sponge city is to the ideal point. Further, according to the degree of closeness, the sponge city will be ranked in descending order to identify the optimal investment ratio.

By the proposed method to measure the operating efficiency of sponge cities, it is no longer necessary to preset or introduce additional human parameters in the evaluation process, making the evaluation results more objective. It aims to build a sponge city operation efficiency measurement index system from the perspective of input and output, which is conducive to relevant managers to measure the operating efficiency of the sponge city, so as to find the problems of low efficiency and improve the efficiency through the management and technical means.

7 REFERENCES

[1] Feng, C. H., Zhang, N., Habiyakare, T., Yan, Y., & Zhang. H. (2021). Prospects of eco-hydrological model for sponge city construction. *Ecosystem Health and Sustainability*, 1994885. https://doi.org/10.1080/20964129.2021.1994885

[2] Pandolfi, G. & Pettinari, J. (2021). Nature-based Solutions for flood management: a study conducted in labaro-prima porta district, Rome, Italy. *Environmental Engineering and Management Journal*, *19*(10), 1835-1846.

[3] Shao, Z. F., Fu, H. Y., Li, D., & Altan, O. (2019). Remote Sensing Monitoring of Multi-scale Watersheds Impermeability for Urban Hydrological Evaluation. *Remote Sensing of Environment*, *232*. https://doi.org/10.1016/j. rse.2019.111338

[4] Kazemi, F., Golzarian, M. R., & Myers, B. (2018). Potential of combined water sensitive urban design systems for salinity treatment in urban environments. *Journal of Environmental Management*, *209*, 169-175. https://doi.org/10.1016/j.jenvman.2017.12.046

[5] Amin, R. (2019). Implementing the 5s: a case study. *Journal of Logistics, Informatics and Service Science*, *6*(1), 1-14.

[6] Islam, R. (2019). Designing sustainable parameters for facilities management to improve operational efficiency. *Journal of System and Management Sciences*, *9*(2), 1-22. https://doi.org/10.33168/JSMS.2019.0201

[7] Goh, H. (2020). Analysis of static and dynamic efficiency for sustainable growth of Edu-tech companies. *Journal of Logistics, Informatics and Service Science*, *7*(1), 87-101. https://doi.org/10.33168/LISS.2020.0107

[8] Qu, Y., Lin, Z. K., Zhang, X. N., & Li, H. L. (2021). A dr-dea production sipplier selection model for green manufacutring considering pllutant discharge. *Environmental Engineering and Management Journal*, *20(*2), 195-202.

[9] Shafifique, M. & Kim, R. (2018). Recent progress in Low-Impact Development in South Korea: Water-management policies, challenges and opportunities. *Water*, *10*, 435. https://doi.org/10.3390/w10040435

[10] Zhang, C. H., He, M. Y., & Zhang, Y. S. (2019). Urban Sustainable Development Based on the Framework of Sponge City: 71 Case Studies in China. *Sustainability* 2019, *11*, 1544. https://doi.org/10.3390/su11061544

[11] Elena-Diana, C., Cristina, G., Raluca, M. H., & Maria G. (2016). Occurrence of plastic waste in the environment: ecological and health risks. *Environmental Engineering and Management Journal*, *3*, 675-687.

[12] Jin, M., Lancia, M., Tian, Y., Viaroli, S., Andrews, C., Liu, J., & Zheng, C. (2022). The role of aquifers in sustaining the sponge city concept in Chinese high-density housing. *Water* 2022, *14*, 929. https://doi.org/10.3390/w14060929

[13] Chen, Z. D., Wu, B. Z., Chen, Y. R., & Sun, Z. (2022). Measurement and Analysis of Construction Efficiency of Sponge City based on super efficiency SBM model. *Water Resoueces and Power*, *40*(8), 157-160. https://doi.org/10.20040/j.cnki.1000-7709.2022.20212665

[14] Li, X. J., Deng, J. X., Xie, W. J., Jim, C. Y., Wei, T. B., Lai, J. Y., & Liu, C. C. (2022). Comprehensive Benefit Evaluation of Pervious Pavement Based on China's Sponge City Concept. *Water*, *14*, 1500. https://doi.org/10.3390/w14091500

[15] Zhu, Y. F., Xu, C. Q., Yin, D. K., Xu, J. X., Wu, Y. Q., & Jia, H. F. (2022). Environmental and economic cost-benefifit comparison of sponge city construction in different urban functional regions. *Journal of Environmental Management*, *304*, 114230. https://doi.org/10.1016/j.jenvman.2021.114230

[16] Li, Q., Wang, F., Yu, Y., Huang, Z., Li, M., & Guan, Y. (2019). Comprehensive performance evaluation of LID practices for the sponge city construction: A case study in Guangxi, China. *Journal of Environmental Management*, *231*, 10-20. https://doi.org/10.48550/arXiv.2112.10347

[17] Wang, Z., Deng, X., & Wong, C. (2016). Integrated land governance for eco-urbanization. *Sustainability*, *8*, 903. https://doi.org/10.2139/ssrn.2739495

[18] Zhou, X. Y., Bai, Z. J., & Yang, Y. H. (2017). Linking trends in urban extreme rainfall to urban Fl flooding in China. *International Journal of Climate Change Strategies and Management*, *37*, 4586-4593. https://doi.org/10.1002/joc.5107

[19] Zhang, N., Luo, Y. J, Chen, X. Y, & Li, Q. (2018). Understanding the Effects of Composition and Configuration of Land Covers on Surface Runoff in a Highly Urbanized Area. *Ecological Engineering*, 125, 11-25. https://doi.org/10.1016/j.ecoleng.2018.10.008

[20] Xu, Z. X. & Zhao, J. (2016). Development and Applications of Eco-hydrological Models: Past and Future. *Journal of Hydraulic Engineering*, *47*(3), 100-108. https://doi.org/10.13243/j.cnki.slxb.20151160

[21] Xu, W., Sun, H. Y., Awaga, A. L., Yan, Y., & Cui, Y. J. (2022). Optimization approaches for solving production scheduling problem: A brief overview and a case study for hybrid flow shop using genetic algorithms. *Advances in Production Engineering & Management*, *17*(1), 45-56. https://doi.org/10.14743/apem2022.1.420

[22] Meili, N., Manoli, G., Burlando, P., & Bou-Zeid, E. (2020). An Urban Ecohydrological Model to Quantify the Effect of Vegetation on Urban Climate and Hydrology (UT&C V1.0). *Geoscientific Model Development*, *13*(1), 335-362. https://doi.org/10.5194/gmd-13-335-2020

[23] Luo, Y. J, Zhang, N., Li, Q., & Wang, X. (2020). Spatial Analysis of the Effects of Urban Underlying Surface and Rainfall Events on Surface Runoff Based on SWMM: A Case Study of Yanqi Lake Campus of University of Chinese Academy of Sciences. *Journal of University of Chinese Academy of Sciences*, *371*, 27-38. https://doi.org/10.7523/ j.2095-6134.2020.01.005

[24] Park, E, Pobil, A. D, & Sang, K. (2018). The Role of internet of things (IoT) in smart cities: Technology roadmap-oriented approaches. *Sustainability*, *10*, 1388. https://doi.org/10.1155/2022/9066215

[25] Meng, X. & Chang, Z. (2022). Research on Subsidy Strategy of Shared Accommodation Platform under the Background of Big Data Based on Evolutionary Game. *Computational Intelligence and Neuroscience*, 9066215. https://doi.org/10.1155/2022/9066215

[26] Nuanmeesri, S. (2021). The Efficiency of Elderly Community Product Using Digital Marketing through Unfolding of Practice during COVID19 Pandemic. *Journal of System and Management Sciences*, *11*(4), 65-86. https://doi.org/10.33168/JSMS.2021.0404

[27] Straka, M., Spirkova, D., & Filla, M. (2021). Improved Efficiency of Manufacturing Logistics by Using Computer Simulation. *International Journal of Simulation Modelling*, *20*(3), 501-512.

[28] Janekova, J., Fabianova, J., & Fabian, M. (2019). Assessment of Economic Efficiency and Risk of the Project Using Simulation. *International Journal of Simulation Modelling*, *18*(2), 242-253. https://doi.org/10.2507/IJSIMM18(2)467

[29] Zhan, W. & Chui, T. F. M. (2016). Evaluating the life cycle net benefifit of low impact development in a city. *Urban Forestry & Urban Greening*, 20, 295-304.

[30] Chidammodzi, C. L. & Muhandiki, V. S. (2017). Water Resources Management and Integrated Water Resources Management Implementation in Malawi: Status and Implications for Lake Basin Management. *Lakes and Reservoirs: Research and Management*, *22*(2), 101-114. https://doi.org/10.1111/lre.12170

[31] Cockburn, J., Cundill, G., Shackleton, S., & Rouget, M. (2018). Towards place-based research to support social-ecological stewardship. *Sustainability*, *10*, 1434. https://doi.org/10.3390/su10051434

[32] Xuan, R. T, Wu, W. & Liu, H. (2013). An experimental study on runup of two solitary waves on plane beaches. *Journal of Hydrodynamics, Ser. B*, *25*(2), 317-320. https://doi.org/10.1016/S1001-6058(13)60369-8

[33] Yu, Y. Y., Li, C. D., Yang, W. M., & Xu, W. (2021). Determining the critical factors of air-conditioning innovation using an integrated model of fuzzy Kano-QFD during the COVID-19 pandemic: The perspective of air purification. *PLoS ONE*, *16*(7), e0255051.

https://doi.org/10.1371/journal

[34] Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, *2*(6), 429-444. https://doi.org/10.1016/0377-2217(78)90138-8

[35] Chen, L., Wang, Y. M., & Huang, Y. (2020). Cross-efficiency aggregation method based on prospect consensus process. *Annals of Operations Research*, *288*, 115-135. https://doi.org/10.1007/s10479-019-03491-w

[36] Liu, J. P., Chen, P. P., Chen, H. Y., & Wang, S. L. (2018). The Ranking method of interval linguistic preference relationship based on cross efficiency DEA and stochastic simulation. *System Engineering - Theory & Practice*, *38*(4), 950-959. https://doi.org/10.12011/1000-6788(2018)34-1950-10

[37] Liern, V. & Pérez-Gladish, B. (2020). Multiple criteria ranking method based on functional proximity index: Un-weighted TOPSIS. *Annals Operations Research*. https://doi.org/10.1007/s10479-020-03718-1

[38] Yu, Y. Y. & Li, C. D. (2021). Evaluate the priority of product design factors in the process of complex product innovation. *Complex & Intelligent Systems*. https://doi.org/10.1007/s40747-021-00298-w

[39] Jia, H., Wang, Z., Zhen, X., Clar, M., & Yu, S. L. (2017). China's sponge city construction: A discussion on technical approaches. *Frontiers of Environmental Science & Engineering*, *11*, 18. https://doi.org/10.1007/s11783-017-0984-9

[40] Li, Z. Z, Dong, M. J, Wong, T., Wang, J. B., Kumar, A. J., & Singh, R. P. (2018). Objectives and Indexes for Implementation of Sponge Cities - A Case Study of Changzhou City, China. *Water*, *10*, 623. https://doi.org/10.3390/w10050623

Contact information:

Ran LI
School of Architecture,
Tianjin University, Tianjin, 10056, China
E-mail: lirantju@gmail.com